(19) Europäisches Patentamt
European Patent Offic
Office européen des brevets

(11) Publication number: 0 219 357 A1

(12) EUROPEAN PATENT APPLICATION

(21) Application number: 86308048.7

(22) Date of filing: 16.10.86

(51) Int. Cl.4: G 02 B 26/08
G 02 B 26/02, H 01 S 3/10

(30) Priority: 16.10.85 GB 8525461
16.10.85 GB 8525458
16.10.85 GB 8525459
16.10.85 GB 8525460
16.10.85 GB 8525462
23.10.85 GB 8526189

(43) Date of publication of application
22.04.87 Bulletin 87/17

(84) Designated Contracting States:
AT BE CH DE ES FR GB GR IT LI LU NL SE

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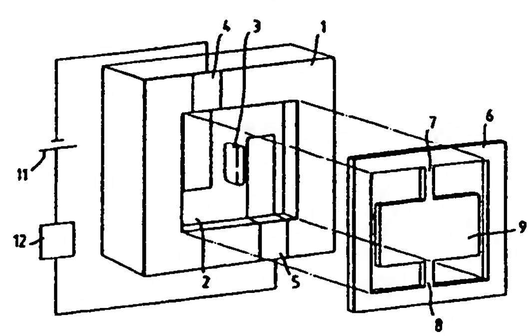
(54) Wavelength selection device and method.

(57) The wavelength selection device comprises a substrate (1); and a deflectable wavelength selection member constituted by a diffraction grating (10) provided by a torsion member (6) mounted to the substrate (1). A pair of electrodes (4,5) are responsive to a control current to cause the torsion member (6) to deflect whereby radiation centres on a predetermined wavelength is selected from radiation having a number of wavelengths impinging on the selection member (10) by setting the selection member (10) at a predetermined angle to the incoming radiation.

Fig.1.



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WAVELENGTH SELECTION DEVICE AND METHOD

The invention relates to a wavelength selection device and a method of selecting radiation centred on a particular wavelength.

It is important when using recently developed laser chips to be able to improve their performance by narrowing the range of wavelengths emitted by the chip. This has been done in the past by positioning a diffraction grating coaxial with the beam emitted by the laser chip and at such an angle to the impinging beam that a selected wavelength is reflected back along the axis towards the laser chip. This angle is the Bragg angle. It has proved quite difficult to do this in the past due to the cumbersome nature of the mounting arrangements which are required to support the diffraction grating particularly when compared with the small dimensions of laser chips.

In accordance with one aspect of the present invention, a wavelength selection device comprises a substrate; a deflectable wavelength selection member provided by a torsion member mounted to the substrate; and control means responsive to control signals to cause the selection member to deflect, whereby radiation centred on a predetermined wavelength is selected from radiation having a number of wavelengths impinging on the selection member by setting the selection member at a predetermined angle to the incoming radiation.

The invention enables a deflectable wavelength selection member to be constructed on a much smaller scale than hitherto by using a microengineering technique thus reducing the problems previously encountered with conventional diffraction gratings.

In accordance with a second aspect of the present invention, a method of selecting radiation centred on a particular wavelength from an original beam of radiation comprising a number of different wavelengths comprises causing the original beam to impinge on a wavelength selection device according to the one aspect of the invention; and causing the wavelength selection member to deflect whereby only radiation having a wavelength centred on the selected wavelength is deflected through a predetermined angle.

Preferably, the wavelength selection member comprises a diffraction grating although other types of selection members could also be used. In the case of a diffraction grating, the surface of the torsion member may be ruled to define the grating.

Conveniently, the diffraction grating comprises a reflection grating although in some circumstances a transmission grating could also be used providing one or more apertures were provided in the substrate to enable transmitted radiation to pass through.

Preferably, the torsion member comprises a torsion plate which is conveniently integrally formed with the substrate. This latter arrangement can be achieved using conventional masking and etching techniques or laser etching techniques particularly where the material from which the substrate is formed is a single crystal of for example silicon when anisotropic etching techniques can be used. The integral arrangement is particularly useful since it reduces the number of separate parts involved and thus improves the integrity of the device.

In some examples, the device may further comprise a selective wavelength transmission member mounted adjacent the wavelength selection member and movable therewith, the selective wavelength transmission member permitting only certain wavelengths of impinging radiation to be transmitted therethrough.

With this arrangement, a two stage wavelength selection operation is carried out. The wavelength selection member (typically a diffraction grating) provides a coarse wavelength tuning element while the additional selective wavelength transmission member provides a fine tuning element.

Although the two members could be mounted separately on the substrate, preferably the members are connected together by one or more spacers.

Conveniently, the selective wavelength transmission member is positioned upstream of the wavelength selection member although an opposite arrangement is also feasible.

Three examples of devices and methods in accordance with the invention will now be described with reference to the accompanying drawings, in which:-

Figure 1 is an exploded plan view of one example;

Figure 2 is a side elevation of the first example shown in Figure 1;

Figure 3 is a view similar to Figure 2 but of a second example; and,

Figure 4 is a plan of a third example, omitting the grating.

The example shown in Figure 1 comprises a single crystal silicon substrate 1 having a square recess 2 in which a central upstanding ridge 3 integrally formed with the base is provided. On either side of the ridge 3 are mounted respective electrode plates 4, 5. A torsion plate 6 is integrally formed with the support ridge 3 and has a pair of torsion bars 7, 8 and a central square portion 9 carrying a diffraction grating 10 (Figure 2).

The arrangement shown in Figures 1 and 2 may be formed using a conventional masking and etching technique and a diffraction grating, which is a reflection grating, can be formed by ruling the surface of the portion 9 before or after the etching process.

As can be seen in dashed lines in Figure 2, the torsion plate 6 can be deflected through an angle about the ridge 3 and this is achieved by generating an electrostatic field between the electrodes 4, 5. The electrodes 4, 5 are connected to a power source 11 and a control element 12 for varying the current applied to the electrodes.

In use, a beam of radiation, typically optical

radiation, is incident on the diffraction grating 10 in a direction indicated by the arrow 13. The torsion plate 6 is deflected through a selected angle. Radiation centred on any particular wavelength will be reflected through the Bragg angle which is unique to each wavelength. In the Figure 2 example it is arranged that radiation centred on a desired wavelength is reflected in the direction of the arrow 14.

In a typical case, the depth of the recess 2 may be about 12.5 microns with the diffraction grating 10 having a square form with a side of 2 mm. The maximum deflection angle may be about 3.5°. If the diffraction grating 10 has a pitch of 600 lines/mm then a 75 nm wavelength shift occurs with a deflection through $1^1/_2$°.

The device shown in Figure 2 may be used in an external cavity associated with a laser chip so that radiation emitted from the laser chip, after collimation, impinges on the diffraction grating and radiation centred on a particular wavelength is then back reflected to the laser chip. In other applications, the device could be used as a source for either direction detection or coherent systems in optical communication systems.

The example shown in Figure 3 is similar to that shown in Figures 1 and 2 except that an additional torsion plate 15 is laminated with spacers 16 to the torsion plate 6. The torsion plate 15 and spacers 16 may be integrally formed with the remainder of the device or alternatively integrally formed together and then bonded to the plate 6. If the torsion plate 15 is made of silicon, this is transparent only at 1.3 and 1.5 microns thus providing a fine tuning element. The remainder of the device functions in exactly the same way as the first example.

The example shown in Figure 4 is an alternative way of providing a torsion plate and is constructed from a relatively thin single crystal silicon substrate using conventional micromachining or anisotropic etching techniques. The assembly comprises a pair of support members 101, 102 between which is mounted a thin plate 103. The plate 103 is mounted between the supports 101, 102 by bridges 104-107. It should be appreciated that the support members 101, 102, the bridges 104-107 and the plate 103 are all integrally formed.

The plate 103 maybe between one and several mm square while the bridges 104-107 will have lengths between 10 and 100μm or more.

A pair of electrically conductive paths 108, 109 are formed between the two support members 101, 102. This is achieved by either doping or metallising respective pairs of bridges 104, 105; 106, 107 and connecting portions of the plate 103 together with adjacent portions of the support members 101, 102. The paths 108, 109 are connected at one end with a common electrical conductor 110 and at the other end to respective electrical conductors 111, 112. The conductors 111, 112 terminate at a switch 113. The switch 113 and the conductor 110 are connected to a current source 114.

In this example, cross-hatching in the drawing indicates electrically conductive parts although portions of these parts may have different resistivities.

In the Figure 4 example, the doping or metallisation is such that the bridges 104-107 have a higher resistivity than the supports 101,102 while the portions of the plate 103 connecting the bridges 104, 105; 106,107 respectively have a low resistivity relatively to the remainder of the silicon plate.

A ruled diffraction grating is provided on the plate 103.

In operation, the switch 113 is connected either to the conductor 111 or the conductor 112 and the current is passed through the respective path 108,109. Due to the relatively high resistivity of the bridges, the passage of a current through the bridges will cause an increase in their temperature and hence result in expansion of the bridge material thus causing deflection of the plate 103. For example, passing a current through the path 108 will cause the bridges 104, 105 to expand and thus the plate 103 will rotate about an axis defined by the path 109. Similarly, a current passed along the path 9 will cause expansion of the bridges 106, 107 and hence rotation of the plate 103 above an axis defined by the path 108.

In a modification, not shown, the same current could be passed through both paths 108, 109 simultaneously. This would result in movement of the plate 103 to a position parallel with its rest position (shown in Figure 4) thus resulting in a piston action. This type of action will be particularly useful where the plate 103 constitutes an end of a laser cavity.

To appreciate the degree of movement involved, consider a bridge having a length of 1 cm. The coefficient of linear thermal expansion for silicon is 2.33×10^{-6}°C^{-1}. Thus a 1 cm length bridge will increase in length to 1.00023 cm for a 100°C temperature rise. This will cause transverse movement of the end of the bridge adjacent the plate of about 0.021 cm. In the case of a piston movement, the sensitivity is thus 0.00021 cm/°C or 2.1 μm/°C. The deflection angle is 1.23°.

It should also be noted that the direction of the deflection can be adjusted by non-uniform doping of the bridges leading to the bridges having different resistivities. This would result in movement which was not about an axis defined by one of the electrical paths.

Our copending application of even date entitled "Movable Member Mounting" (Case 23332/GB) discusses the Figure 4 example in more detail.

Claims

1. A wavelength selection device comprising a substrate; a deflectable wavelength selection member provided by a torsion member mounted to the substrate; and control means responsive to control signals to cause the selection member to deflect, whereby radiation centred on a predetermined wavelength is selected from radiation having a number of wavelengths impinging on the selection member by setting the selection member at a predetermined angle

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to the incoming radiation.

2. A device according to claim 1, wherein the wavelength selection member comprises a diffraction grating.

3. A device according to claim 2, wherein the diffraction grating comprises a reflection grating.

4. A device according to any of the preceding claims, wherein the torsion member comprises a torsion plate.

5. A device according to any of the preceding claims, wherein the torsion member is integral with the substrate.

6. A device according to any of the preceding claims, further comprising a selective wavelength transmission member mounted adjacent the wavelength selection member and movable therewith, the selective wavelength transmission member permitting only certain wavelengths of impinging radiation to be transmitted therethrough.

7. A device according to claim 6, wherein the selective wavelength transmission member and the wavelength selection member are connected together by one or more spacers.

8. A device according to claim 6 or claim 7, wherein the selective wavelength transmission member is mounted upstream of the wavelength selection member.

9. A device according to any of the preceding claims, wherein the substrate comprises silicon.

10. A wavelength selection device substantially as hereinbefore described with reference to any of the examples shown in the accompanying drawings.

11. A method of selecting radiation centred on a particular wavelength from an original beam of radiation comprising a number of different wavelengths, the method comprising causing the original beam to impinge on a wavelength selection device according to any of the preceding claims; and causing the wavelength selection member to deflect whereby only radiation having a wavelength centred on the selected wavelength is deflected through a predetermined angle.

12. A method of selecting radiation having a particular wavelength substantially as hereinbefore described with reference to any of the examples shown in the accompanying drawings.

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Fig.1.

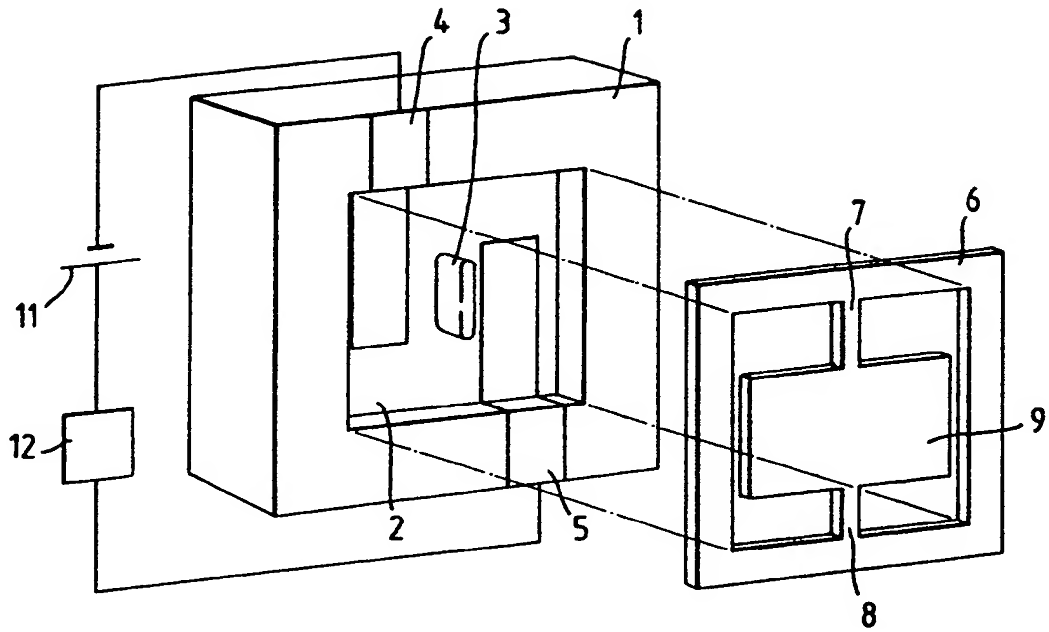

Fig.2.

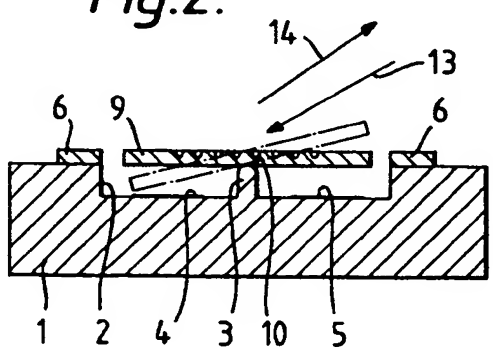

Fig.3.

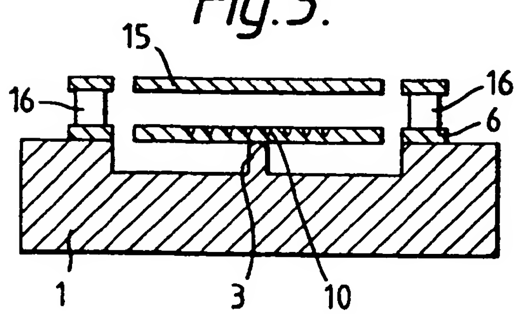

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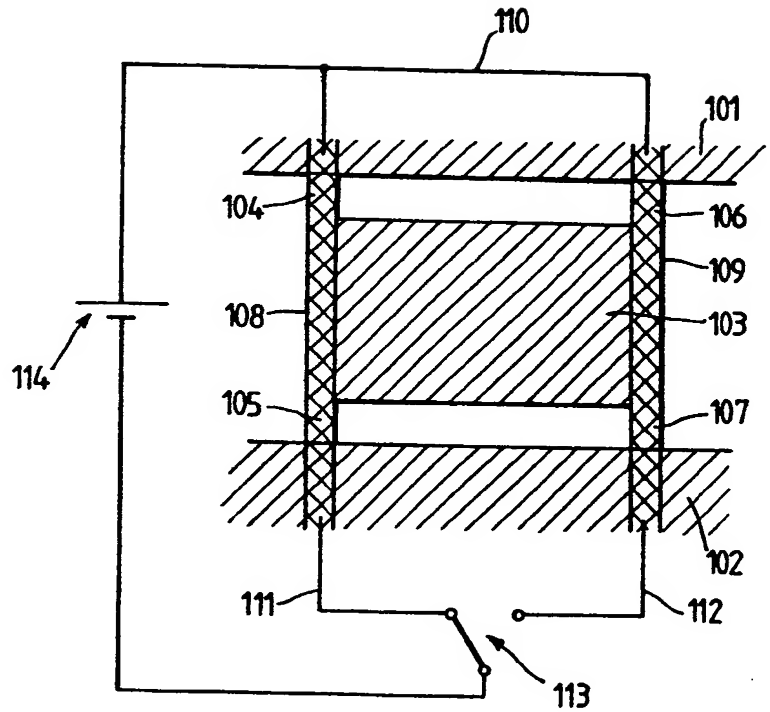
Fig.4.



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EUROPEAN SEARCH REPORT

Application number

EP 86 30 8048

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
Y	EP-A-0 040 302 (IBM CORP.) * Claims; figures *	1-5,9-12	G 02 B 26/08 G 02 B 26/02 H 01 S 3/10
A		6-8	

Y	PATENTS ABSTRACTS OF JAPAN, vol. 9, no. 257 (P-396)[1980], 15th October 1985; & JP-A-60 107 532 (TOSHIBA K.K.) 13-06-1985	1-5,9-12	
A	Idem	6-8	

A	US-A-4 115 747 (M. SATO) * Whole document *	1,2,6,11	
	---		TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US-A-4 450 563 (S. BEPKO) * Whole document *	1,2,6,11	G 02 B 26/08 G 02 B 26/02 G 02 B 26/10 G 01 J 3/18 H 01 S 3/08 H 01 S 3/10

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26-11-1986	WESBY P.B.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
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O : non-written disclosure
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T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
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